PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

Public Health Benefits of End-Use Electrical Energy Efficiency in California: An Exploratory Study

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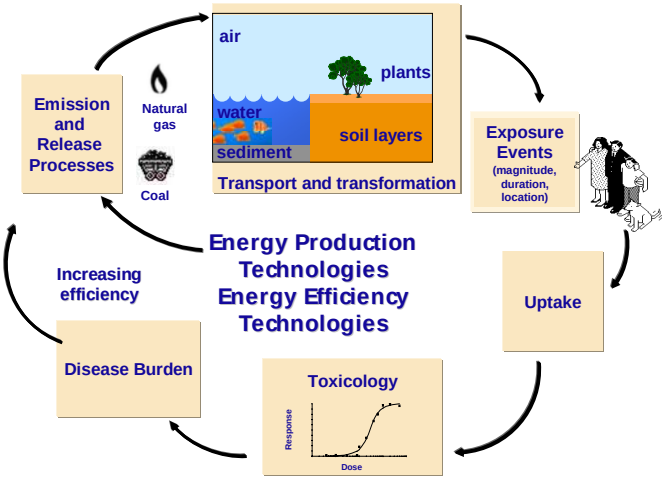
The Issue

Providing electricity to California results in potentially significant health and environmental impacts. The Externalities of Energy (ExternE) research project of the European Commission has evaluated public and occupational impacts for a number of energy production technologies. ExternE reports that the value of public and occupational health impacts attributable to energy use is on the order of $25,000 per gigawatt-hour (GWh) produced from coal-fired power plants and $4,000 per GWh produced from natural gas power plants.[1] In 2001, California produced 10% or 27,636 GWh of its electricity from coal and 43% or 113,145 GWh of its electricity from natural gas.[2]



Various emissions from fossil-fired electric generation have adverse impacts on human health and the environment. These emissions can be reduced by (1) using cleaner generating technologies, and/or (2) using more efficient end-use technologies, so that less electricity needs to be generated in the first place.

Over recent decades, several studies have attempted to quantify the health and environmental impacts of various energy systems. However, because these comparative studies have excluded end-use energy efficiency from the mix of technologies considered, there remains an important gap in the information available to policy makers for making informed decisions on California's energy choices. This project will facilitate better understanding of the human health implications

[1] ExternE. 2004. Externalities of Energy, a research project of the European Commission. Reports on methods and findings are available at http://externe.jrc.es/index.html.

[2] California Energy Commission. website 2002, http://www.energy.ca.gov/html/energysources.html.

of both supply side (power generation) and demand side (end use) technologies and efficiency measures.

Project Description

This exploratory project applied standard methods of life-cycle impact assessment (LCIA) to the problem of quantifying both the public health hazards avoided and those substituted by increasing the efficiency of electricity end-use in California. The conceptual framework was demonstrated through a case study, which quantified the changes in power plant emissions and associated disease burden resulting from the installation of fiberglass attic insulation in the nearly 3 million electricity-heated homes throughout California. These estimates were compared with the disease burden from the manufacture of fiberglass insulation to determine the net health impact of installing the attic insulation.

The case study focused on nitrogen oxides (NO_x), sulfur dioxide (SO_2), fine particulate matter ($PM_{2.5}$), benzo(a)pyrene (BaP), benzene, and naphthalene emissions from California power plants. Pollutant exposure was characterized separately for urban and rural populations using an existing LCIA tool, the UC Berkeley CalTOX model. This multimedia fate and exposure model is used for exposure assessment in the US Environmental Protection Agency's Tool for the Reduction and Assessment of Chemicals and other environmental Impacts (TRACI)[3]. The output from CalTOX provided separate urban and rural emissions-to-intake factors, which were expressed as an individual intake fraction (*iFi*). The cumulative (rural and urban) product of emissions, population, and *iFi* was combined with toxic effects factors to determine human damage factors (HDFs), which were expressed as disability-adjusted life years (DALYs) per kilogram of pollutant emitted. Through the DALY metric, the analytical framework allows all negative health outcomes—not just mortality—to be expressed as a single measure of disease burden.

Emissions from the manufacture of each additional megatonne of fiberglass were calculated, and the DALYs incurred by those emissions were compared to the DALYs saved from use of the insulation.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound electricity.** The framework developed in this project will enable reliable and transparent calculations of the net benefits of energy efficiency specific to the California market, as well as more explicit consideration of environmental effects within the broader decision making process. By facilitating direct comparison of supply and end-use technology options, this study will help policy makers determine which options provide the lowest emissions per GWh of electric production.
- **Reducing California's health costs.** Based on California Energy Commission data for coal- and natural gas–based power production for California and the ExternE numbers for health impacts, the estimated value of health impacts from these two power sources alone amounts

[3] Bare, J.C., Norris, G., Pennington, D.E., and McKone, T.E. 2002. "TRACI – The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts," *Journal of Industrial Ecology* 6(3-4): 49–78.

to an annual equivalent disease burden of approximately $1.1 billion in California. Although these preliminary estimates are based on numbers that have not been fully validated for California, they reveal the significant health benefits that could be achieved for every fraction of fossil-fueled power generation that is avoided through energy efficiency measures.

Results

Typical individual intake fractions (*iFi*) from power plant emissions were found to be on the order of 10^{-13} (10^{-15} for BaP) in urban and rural regions. Health impacts were dominated by premature mortality due to inhalation of $PM_{2.5}$. Human damage factors for $PM_{2.5}$ were roughly two orders of magnitude greater than inhalation exposure HDFs for the other five chemicals.

Upgrading existing residential attic insulation to levels recommended by the US Department of Energy was found to eliminate—over the estimated 50-year lifetime of the insulation—approximately 1000 DALYs from power plant emissions per megatonne (Mt) of insulation installed, mostly from the elimination of $PM_{2.5}$. In comparison, the estimated disease burden from the manufacture of this insulation is roughly four orders of magnitude lower than that avoided. This translates to a net avoidance of approximately 110 premature deaths over the 50-year lifetime of the insulation—mostly due to a reduction in $PM_{2.5}$ emissions.

This study was successful in organizing the roadmap, data, and computational tools needed to assess both disease burden and health benefits from changes in electricity consumption in California. The framing of this problem produced a repository of important information that will be useful for future comparative studies. The successful application of the TRACI-CalTOX LCIA approach reveals the value of exploring how this system could be applied to life-cycle studies of other energy production and energy efficiency technologies.

Final Report

The final report for this project is posted on the Energy Commission's website at http://www.energy.ca.gov/2006publications/CEC-500-2006-116/CEC-500-2006-116.PDF.

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